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THE BAUXITE¹ DEPOSITS OF ARKANSAS.

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THE geological survey of Arkansas was begun in June 1887. In that month I discovered some of the bauxite beds of Pulaski county, but the nature of these deposits was not announced until January 1891, when I gave a short account of their distribution and character.²

The many inquiries concerning the Arkansas bauxites, both from geologists and manufacturers, furnish sufficient reason for the present more extended account of them. This is made still more necessary by the fact that my report on the clays, kaolins, and bauxites of Arkansas has not yet been published, and it seems improbable that it ever will be published by that state.

In view of the fact that Owen was State Geologist of Arkansas from 1857 to 1860, and that other surveys were carried on

¹ This is also sometimes written *beauxite*. The word is derived from Les Baux or Les Beaux, the name of a town in the south of France. Pronounced *bozite*, not *bawksite*.

² A letter on this subject was addressed to Governor James P. Eagle and was printed in the *Arkansas Gazette* and the *Arkansas Democrat* of January 8, 1891, and reproduced in the *Arkansas Press* in several numbers from January 18, 1891, until 1893, and also in the third and fourth biennial reports of the Commissioner of Mines, etc., of the state of Arkansas. A brief notice of the deposits was also published in the *American Geologist* for March 1891, pp. 181-183.

from 1871 till 1874,¹ it is somewhat remarkable that the bauxite deposits were not sooner discovered. The rocks were seen and mentioned by two geologists, but their true character and importance were not suspected. As long ago as 1842 Dr. W. Byrd Powell published a brief paper on the geology of Fourche Cove, near Little Rock, in which he says:² "There is an extensive amygdaloid formation within the cove, and also upon the eastern side of it (page 11) The amygdaloid proper is of a light brick color. In some localities it is darker, and in others lighter At one locality the amygaloids are small, resembling a mass of peas, but each amygaloid, or pea-like body, is hollow, having a shell not thicker than that of an egg. At another the amygdaloids are filled, but they, as well as the cement or gangue, are earthy and more or less friable." There can be no doubt that some of these so-called amygdaloids are the bauxites.

It is evident, however, that some of the tertiary conglomerate beds were regarded by Dr. Powell as variations of these "amygdaloids," for he says that some of them consist of jasper (p. 12).

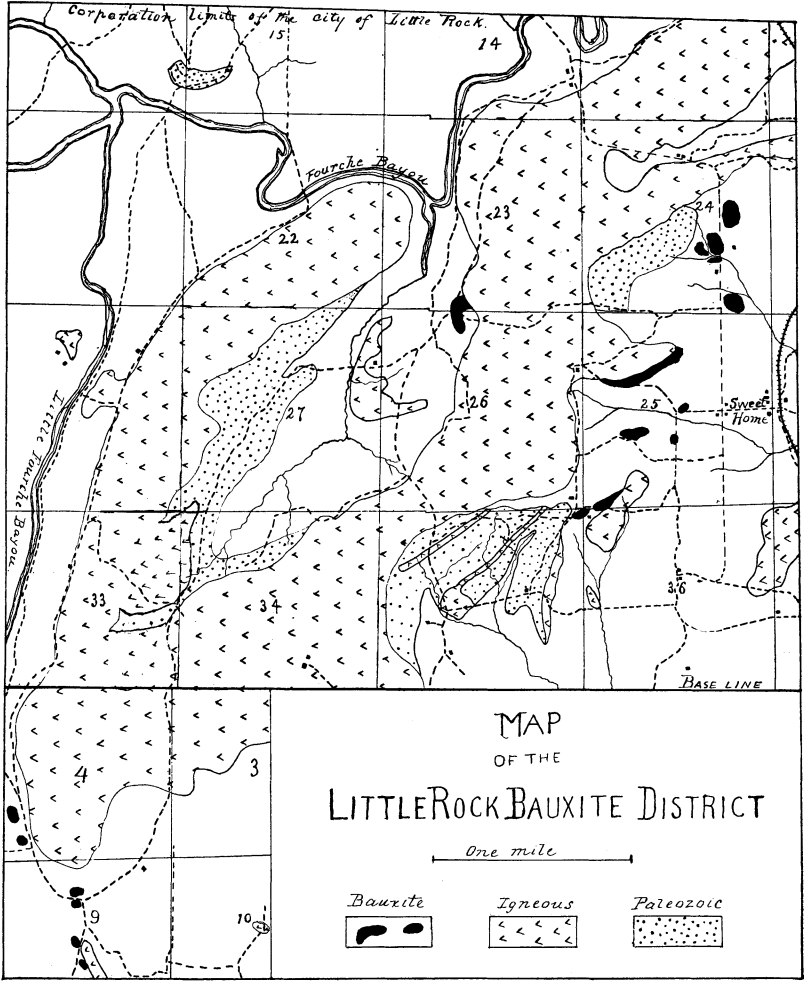
Owen also mentions this "ferruginous amygdaloid of rather a peculiar character," and says that "the amygdules are very globular, so that the rock has much the appearance of peastone, the cavities being mostly empty."³ The description of the rock and the locality given make it clear that the bauxite rock is here referred to, and yet there is no word to show that either Powell or Owen knew or suspected the true nature of the material.

That these observers did not recognize this mineral is probably due to the fact that bauxite was, at that time, but little

¹See the Geological Surveys of Arkansas, by J. C. BRANNER. *JOUR. OF GEOL.* II, November-December 1894, 826-836.

²A geological report upon the Fourche Cove and its immediate vicinity, by W. BYRD POWELL, M.D., Little Rock, 1842, 11-13. This is a very rare pamphlet; I know of but one copy of it, and that is in the library of the U. S. Geological Survey.

³Second report of a geological reconnoissance of Arkansas. By DAVID DALE OWEN, Philadelphia, 1860, 70.



known even in Europe, and it was altogether unknown in America.

At the time when it was found that this rock was bauxite (1887) it was being used extensively for making the roadbed of the Little Rock and Sweet Home turnpike, especially along the part of the road near one of the bauxite beds. It had also been recommended by a former state geologist, Mr. W. F. Roberts, Sr., as a "pisolitic iron ore," and attempts had been made to mine some of the highly colored Saline county beds for iron.

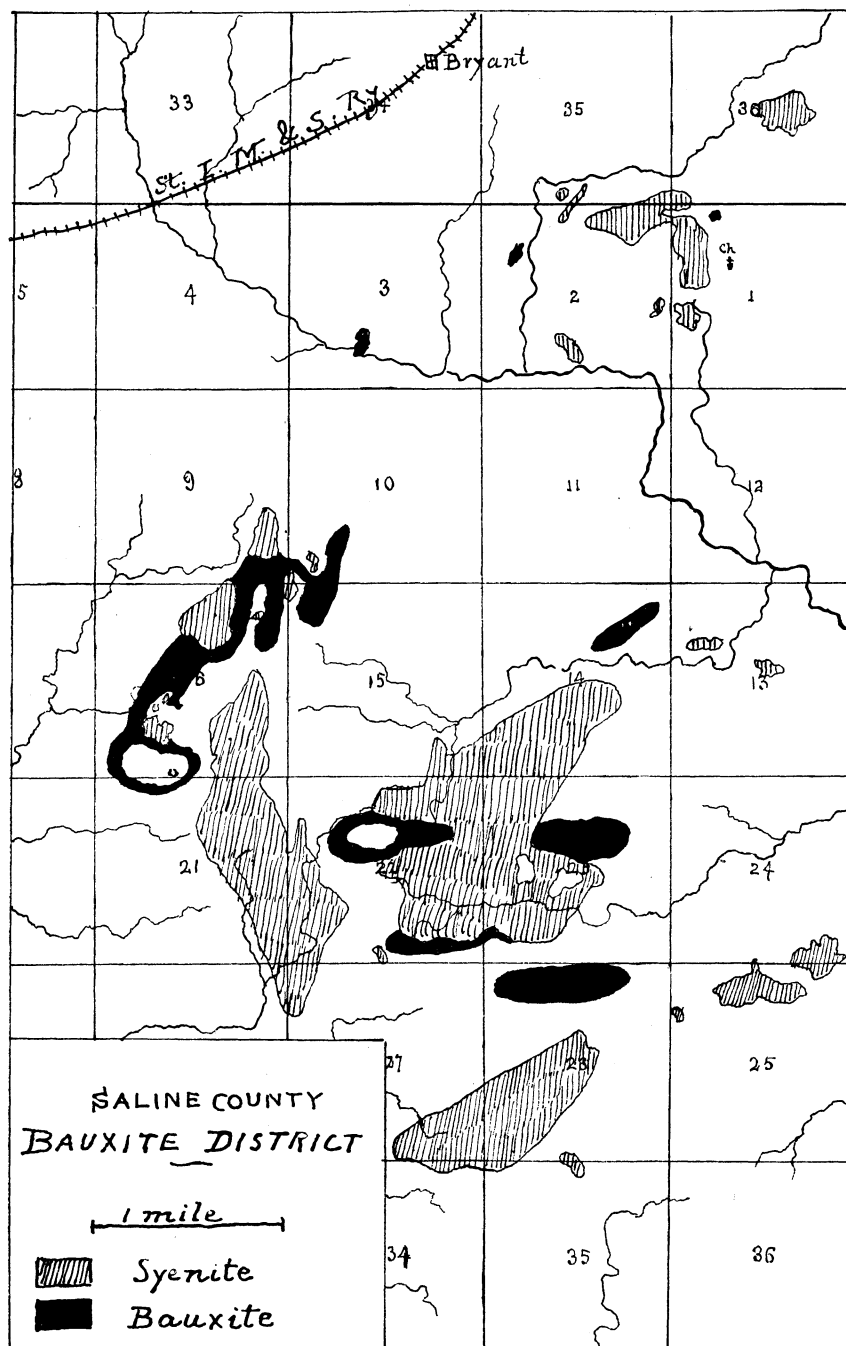
Definition and composition.—It is practically impossible to draw a sharp line of division between bauxite as defined mineralogically and what appears in a hand specimen to be the same thing, but which on analysis is found to contain one or another impurity in such proportions as to throw it out of the bauxite list. Mineralogically bauxite is a hydrate of alumina,¹ but it is never found without certain impurities, the common ones being iron, silica, potash, soda, and titanium. All these impurities are found in the Arkansas bauxites, and in some cases the iron is so abundant that the beds have been prospected with a view to using the material as an ore of iron. The following analyses of some of the more ferruginous varieties show its iron contents:

ANALYSES OF FERRUGINOUS PISOLITIC BAUXITE.

Number	Percentage of iron	Phosphorus	Silica
1.....	66.85	.043	not det.
2.....	54.2	.048	not det.
3.....	59.2	.031	not det.
4.....	54.9	.10	1.99

No. 4 was collected by the writer in 2 S. 14 W. section 1, northwest quarter; the other numbers are from the Saline

¹ St. Claire Deville regards it as a variety of Diaspore ($\text{Al}_2\text{O}_3\text{H}_2\text{O}$); Dufrenoy thinks it is close to Gibbsite ($\text{Al}_2\text{O}_3\cdot 3\text{H}_2\text{O}$), while Liebrich shows it to be closely related to or identical with Hydrargillite.



county deposits, but they were collected by prospectors for iron ore, and their exact locations are not known.

In other cases the bauxite contains so much silica and so little water that it is not to be distinguished by analysis from ordinary kaolin. And these varieties grade so insensibly into each other that no line of demarkation can be drawn between them. The following analyses show the similarity in composition between a kaolin and a variety of bauxite, which, properly speaking, is simply a pisolitic kaolin.

ANALYSES OF PISOLITIC AND ORDINARY KAOLINS.

	Pisolitic kaolin 1 S. 13 W., sec. 10 N. E. of N. E.	Pisolitic kaolin Same sec., S. E. of N. W.	Washed kaolin from Brandywine Summit, Pa.
Silica, SiO_2	48.05	45.20	47.24
Alumina, Al_2O_3	38.92	37.60	37.27
Ferric oxide, Fe_2O_3	1.19	3.00	1.04
Lime, CaO	0.58	.89	0.52
Magnesia, MgO	0.45	.00	trace
Potash, K_2O	0.18	.06	0.22
Soda, Na_2O	0.28	.69	0.13
Water.....	10.86	13.54	13.62
Total.....	100.51	100.98	100.94

Water at $110^\circ\text{--}115^\circ\text{C}$0.46 %.....1.48 %

In the following table are brought together all the analyses of the Arkansas bauxite, and a few analyses of representative bauxites from other parts of the world.¹ These analyses are of individual examples, however, and must not be accepted as if made of car-load lots.

¹In the article published in the *American Geologist* for March 1891 I gave an average of fourteen partial analyses of bauxite from France, Austria, and Ireland. I wish here to express my disapproval of such a method of making comparisons. Owing to the extreme variability of bauxites, even from the same beds, such an average can scarcely fail to be misleading. If material is wanted with a low percentage of silica the high percentage in some of the samples will so increase the silica in the average that one may be led to infer that none of it is low enough to be available—a conclusion entirely unwarranted.

ANALYSES OF ARKANSAS AND FOREIGN BAUXITES.

	Silica SiO ₂	Alumina Al ₂ O ₃	Iron Fe ₂ O ₃	Titanic oxide TiO ₂	Water H ₂ O	Color
1.....	10.13	55.59	6.08	....	28.99	Light brown
2.....	11.48	57.62	1.83	....	28.63	Gray
3.....	3.34	58.60	9.11	....	28.63	Light red
4.....	4.89	46.44	22.15	....	26.68	Brick red
5.....	5.11	55.89	19.45	....	17.39	Black
6.....	33.94	44.81	1.37	2.00	17.88	Gray, surface
7.....	2.00	62.05	1.66	3.50	30.31	Pink
8.....	10.38	55.64	1.95	3.50	27.62	Surface
9.....	16.76	51.90	3.16	3.50	24.86	
10.....	45.20	37.60	3.00	....	13.54	{ Lime 0.89 Potash .06 Soda .69 White, pisolitic
11.....	21.70	58.10	3.00	3.20	14.00	White
12.....	2.80	57.60	25.30	3.10	10.80	Red
13.....	6.29	64.24	2.40	some	25.74	

1. 1 north, 12 west, section 24, north side of the southeast quarter. On Little Rock Sweet-Home turnpike, cut near road.

2. 1 north, 12 west, section 25, southwest corner, and section 36, northwest corner. Tarplay's.

3. 2 south, 14 west, sections 9 and 10; extending also from 10 into northwest of 15.

4. 2 south, 14 west, section 3, southeast of the southwest.

5. 2 south, 14 west, section 3, southeast of the southwest.

6. 2 south, 14 west, section 16, northeast corner of the southwest quarter near Sol. Nethercut's.

7. 1 south, 12 west, section 9, northwest quarter of the northeast quarter, at the end of the Arch Street Pike, and just north of the fork of the road at the point mentioned.

8. 1 south, 12 west, section 4, middle of the south side of the northwest of the southwest quarter on the west side of the Arch Street Pike leading south from Little Rock. Exposure in the field, a stone's throw from the road.

9. 1 south, 12 west, section 9, northeast quarter of the northwest quarter, west of the pike and west of small stream, about 100 feet south of bridge.

10. 1 south, 13 west, section 10, southeast quarter of the northwest quarter.

11. Baux, near Arle, France (Sainte-Claire Deville).

12. Revest, near Toulon, France (Sainte-Claire Deville).

13. Near Feistritz, Styria.

The analysis must determine the value of bauxite, but it should not be forgotten that varieties not available for one purpose may sometimes be used for some other purpose. As a rule, however, silica, iron, and titanium are the objectionable ingredients. When the percentage of silica reaches that in kaolin or clay the bauxite has no advantage over kaolin or clay for the purposes for which it is used.

Mr. McCalley, in his valuable paper upon Alabama bauxite, calls attention to the fact that the surface material contains more silica than samples taken at a depth.¹ This had escaped attention in my brief examination of the Arkansas bauxite, but since reading Mr. McCalley's paper I recall the fact that this view is borne out by the analyses of the Arkansas materials so far as they have been made. If this is a fact that can be depended upon as constant, it is one of great importance in mining bauxite.

In the ferruginous, earthy, and kaolin-like varieties the pisolitic structure is always more or less pronounced in the Arkansas bauxite.

Structure and appearance.—Bauxite is very light; its specific gravity is about 2.4. In gross structure, color, texture, and general appearance Arkansas bauxite varies greatly. The colors are red, pink, brown, black, gray of various shades, white and yellow, and these colors are also more or less mixed in the same deposit, and even in the same hand specimen.

The several classifications or subdivisions proposed by Coquand, Laur and others will, in all probability, hold with the Arkansas deposits, but inasmuch as these divisions all grade insensibly into each other it seems unnecessary to give those classifications or to lay any stress upon them. Chemical analyses and the practical availability of the different varieties can alone be

¹Proc. Ala. Ind. and Sci. Soc., Vol. II, 1892, p. 29.

depended upon. I may add, however, as a suggestion of possible utility that the red varieties are not all high in iron as one might suppose; some of the reddest examples found in Saline county contain very little iron.

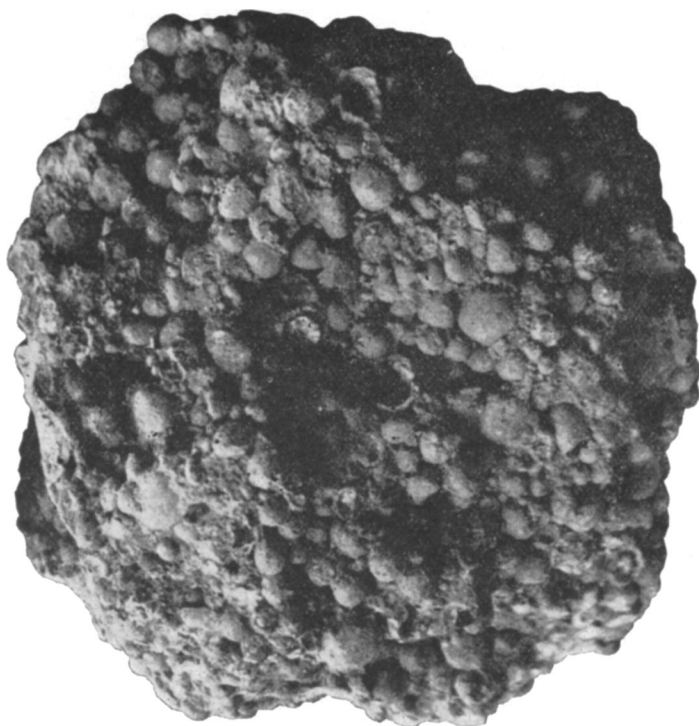


FIG. 1. Pisolitic Bauxite from near Little Rock.

Some of the pisolites are solid and some of them are hollow; sometimes they are scattered through a more compact and homogeneous groundmass, and at other times they make up the body of the rock and resemble a great mass of peas cemented together.

The accompanying illustration (Fig. 1) shows a specimen of the more pisolitic variety taken from the deposits in township 1 south, 12 west, section 4, southwest quarter.

The pellets are in some place much larger, the biggest being the size of one's two fists or even larger.

Bauxite is sometimes compact. Mention should be made of the fact that while one often sees small pieces of the compact variety, there are, so far as I know at present, no beds or considerable deposits of the compact kind in Arkansas.

I have seen in the Royal College of Sciences in Dublin specimens of the compact bauxite of Ireland. That material looks very like a compact and homogeneous clay, and has no evidences of pisolitic structure. Bauxite of this variety I have not found in Arkansas.

The heavy beds in Saline county are in some respects different from those at the other Arkansas localities. In small fragments this material is not distinguishable from that found near Little Rock, but the beds are, in places, made up of what seem to be cobbles or rolled and waterworn lumps of the same material. Some of these lumps are as large as a man's head.

Under the microscope one specimen shows the pisolites to be concentric in structure, while here and there through them are thin bands or veins of quartz. This suggests that the silica found by analysis is sometimes free.¹

Geologic age.—Bauxite has been found in Arkansas only in Tertiary areas and in the vicinity of eruptive syenites with which I believe them to be genetically related. This statement concerning areal distribution must be accepted simply as a statement of fact, but one that may be of considerable importance in Arkansas, and possibly of none whatever in other bauxite regions. The evidence of the Tertiary age of the Arkansas bauxite is not abundant, but it all points in one direction.

At the village of Ridgewood, about five miles south of Little Rock, a well dug on lot 11 exposed the following section:

Section of well on lot 11, village of Ridgewood.—

3 feet surface soil.

7 feet pisolitic bauxite.

¹ For a good microscopic view see paper of C. W. HAYES in the 16th Ann. Rep. U. S. G. S., Part III, Plate XXIII.

2 inches iron (limonite.)

6 inches pink and white clays.

The pink and white clays at the bottom of this well belong with the horizontally stratified Tertiary beds of the neighborhood. There are no fossils, however, in these clays, and they are considered as Tertiary solely upon lithologic and stratigraphic grounds.

At Tarplay's place in the northwest corner of section 36, 1 north, 12 west, the bauxite has a thin bed of Tertiary or post-Tertiary sandstone overlying it. At Mabelvale in 1 south, 13 west, section 10, northwest quarter, the same kind of ferruginous sandstone overlies bauxite. It should be added also that the bauxite at several places overlies the eruptive syenites or so-called "granites," while at several others it is very probable that there are syenites beneath them. These syenites are apparently of late Cretaceous or post-Cretaceous Age.

It is not to be inferred, however, that bauxite is confined to Tertiary rocks, except perhaps in Arkansas. I see no reason why the conditions that produce this mineral might not exist in one age as well as in another, though these conditions are likely to occur in one age in one place and in another age at another place.

The statement of Laur that "the phenomena which gave rise to the bauxites in Europe occurred with great intensity toward the end of the Cretaceous epoch, and has never been repeated"¹ is probably unwarranted.

In southern France bauxite is said to form the parting between the Cretaceous and the Jurassic. Coquand says it is in the *Iychnus* beds of the Upper Cretaceous.² Collot shows that it lies between the Urgonian below and the Cenomanian above, that is, about the junction between Lower and Upper Cretaceous.³ Rouville says the pisolitic iron of Herault is in the "Oxfordian" or Upper Jurassic, if by "Oxfordian" he means

¹ Trans. Amer. Inst. Min. Eng. 1896.

² Bull. Soc. Géol. 1870-1, XXXVIII, 111.

³ Compt. Rend. 1887, CIV, 129-130.

the Oxford clays of the English geologists.¹ Fabre found it in crevices in Jurassic rocks,² but deposited in early Tertiary times, while that referred to by Dr. Raymond in a corundum mine in North Carolina is believed to be in eruptive rock,³ the age of which is not stated. The Irish bauxites are associated with eruptive rocks of Tertiary Age.⁴

The Alabama bauxite deposits are said⁵ by McCalley to be of Lower Silurian Age, but Hayes thinks⁶ the Alabama and Georgia deposits were formed "toward the close of the Eocene."

These cases are cited simply to show that bauxite is not confined to rocks of any particular age, except perhaps in a given region. I have seen it stated that bauxite has been found recently near the Maumelle Pinnacles, about fifteen miles up the river from Little Rock. This would bring the deposits into rocks of Carboniferous Age. This report lacks confirmation; I know of neither bauxite nor syenite in that region. It is important to notice, however, that if the writer's theory of the origin of these deposits is correct, search for them in Arkansas should be confined to the neighborhood of the eruptive syenites,⁷ though not all these syenites have bauxite deposits in their vicinity. The eruptive rocks at Magnet Cove are mostly syenites, but no considerable bauxite deposits have been found associated with them. Some small fragments were found by me in the Cove on the north slope of the hill just south of the Baptist church.

Origin of the Arkansas bauxite deposits.—In searching for new deposits and in determining the limits of those already known, we must be guided to a certain extent by a knowledge of the method

¹ Bull. Soc. Géol. de France XXV, 1867-8, 935.

² Bull. Soc. Géol. de France, 1869-70, XXVII, 518.

³ Trans. Amer. Inst. Min. Eng. VII, 86.

⁴ Memoirs of the Geol. Survey [of Ireland] to accompany sheets 7, 8, 14, 20. By R. G. SYMES.

⁵ Alabama bauxite. By HENRY MCCALLEY. Proc. Ala. Ind. and Sci. Soc., 1892, II, 21.

⁶ Bauxite. By CHARLES W. HAYES, 16th Ann. Rep. U. S. Geol. Sur., Part III, 592. Washington, 1896.

⁷ For the distribution of eruptive rocks in Arkansas see Vol. II of the annual report of the Geological Survey of Arkansas for 1890.

by which the deposits have been made, for it is only in this way that we can anticipate the peculiarities of its distribution. There is therefore given below, as briefly as possible, the several theories that have been advanced to explain the method by which bauxite deposits have been made.

The Arkansas beds appear to have been laid down in water near the shore, but the material does not seem to have been car-



FIG. 4. Ideal Section through Fourche Cove.

ried far from the spot at which it originated, or to have been widely distributed by the water. They are all at or near the contact between the palæozoic sediments and the eruptive syenites. Several of them, however, have no palæozoic rocks exposed near at hand, and one of them has no syenite exposures. These conditions are shown in part by the following ideal section illustrating the relations of the rocks about the Fourche Cove.

The concretionary structure of the bauxite suggests that it has been formed in some such manner as the oölites or sprudelsteins of the well-known hot springs at Carlsbad. At this last named place the oölites are made of carbonate of lime. The water is charged with lime, and as it issues the lime collects about centers. These masses are kept in motion in the rising waters until by accretion they become so heavy that they sink to the bottom.

Oölites are also made in various other ways, such as the rolling of grains upon a shore and in waters heavily charged with lime, by lime secretions of certain algæ¹ and other organisms,² and possibly by insect eggs as suggested by M. Virlet d'Aoust.³

¹ On the formation of oölit. By DR. A. ROTHPLETZ. Amer. Geol. X, 279-282.

² The formation of oölit. By E. B. WETHERED. Quar. Jour. Geol. Soc., LI, 1895, 196-209.

³ The Geologist (I), 1858, 72-73.

Attention is directed to the peculiar nature of some of the great beds of Saline county; there the strata are composed of rolled or waterworn lumps as large as one's head which, when broken open, show the same pisolitic structure as that found at other places. It looks as though the material had been deposited in water near the shore, and that it had been partly uncovered at low tide or broken up by storm waves, and that its earthy material had been broken and rolled by the waves, and finally left at or near where it had originally lain. None of the beds examined show the lamination or thin bedding planes so characteristic of sedimentary rocks.

These facts seem to point to an origin for bauxite very similar to that of calcareous pisolites, and its association with the syenites suggests that the latter have something to do with the matter. I am of the opinion that the explanation offered by Coquand, Augé, de Rouville,¹ Virlet d'Aoust,² Daubrée,³ and Hayes is the correct one so far as hot waters are concerned, but I am unable to see why they should have been geyser waters. Augé has cited⁴ from Hayden's report of 1878, Part II, p. 416, what he considers a case of bauxite actually forming in a geyser. This, however, is a mistake; I have examined in the United States National Museum the material referred to; it has no resemblance to bauxite, and Professor George H. Merrill tells me that it is a geyser mud or kaolin mechanically churned up by the water and from which the silica has been removed. Strangely enough this error has been extensively copied and is found in many of the papers on bauxite, even as late as that by M. Lauer published in 1895.

Dr. Genth holds that the bauxite may be derived by hydration from corundum, but frankly admits that he cannot explain the transformation.⁵

¹ Bull. Soc. Géol. de France, 1867-8, XXV, 935.

² Op. cit., XV, 199; XXII, 418-420.

³ Op. cit., XXVI, 915.

⁴ Bull. Soc. Géol. de France, 1888, XVI, 345-350.

⁵ Proc. Am. Phil. Soc. Vol. XII, 373 and 405.

Coquand says:¹ "The aqueous origin of the bauxites is as well marked by their structure as by their stratification and alternation with sandstones, limestones, and clays. It is evident that the sedimentation (at the time the deposits were made) began at the bottom of a lake by the deposition of aluminous and calcareous matter brought in from mineral sources and to which a certain movement of the waters gave a pisolitic form." It is not altogether clear what M. Coquand means by the "mineral sources" to which he refers several times and to which he attributes the material of the bauxites. His paper ends with the conclusion that the several bauxite localities of France "are of the same age and fall under the head of irregular deposits of geyser origin," from which it must be inferred that he thinks the hot waters of geysers are the "mineral sources" from which the bauxite has been derived.

M. Stanislas Meunier holds² that salt water penetrating to great depths can, on account of its high temperature and the pressure upon it, dissolve the ferruginous shales and form chlorides of alumina and perchlorides of iron. When these chlorides come to the surface and spread over limestones, as they usually do, a change of bases takes place, alumina and peroxide of iron are precipitated, chloride of lime is carried away and the carbonic acid of the limestone is set free, while the iron and alumina is deposited as bauxite.

Augé, as stated in the article already referred to, was led to reject Meunier's theory by finding bauxite resting on rocks other than limestones. To this Meunier replies that the chemical changes demanded by his theory might be produced by the waters carrying the material passing over limestones and depositing the bauxite further on in their course.

Daubrée says³ that while generally associated with sedimentary beds, the bauxite beds show their relations to deep-seated emanations by the presence of anhydrous peroxyde of iron or

¹ Bull. Soc. Géol., 2^{me} ser., 1870-1, XVIII, 98 ff.

² Bull. Soc. Géol., 3^{me} ser., XVI, 1888, 345-346.

³ Bull. Soc. Géol. de France, XXVI, 1868-9, 915.

oligiste, which generally colors them, and by its ramifications generally penetrating underlying beds and by the juxtaposition to granite.

R. G. Symes thinks that the bauxite at Estertown, County Antrim, Ireland,¹ "seems to be a mud lava."

The most exhaustive study yet made of bauxite is that of Dr. A. Liebrich, the title of whose treatise is given in the bibliography at the end of this paper. He quotes Streng as holding that the Vogelsberg bauxite is derived from basalt by decomposition, and, in general terms, Liebrich endorses this view. Further on, however, he states that it is "not the decomposition product of an underlying basalt, but of a completely disintegrated anamesite lying above a compact basalt." Again he says: "There is nowhere bauxite containing a kernel of stone which is not a decomposition product." Again "the transition between bauxite and basaltic hematite may be traced step by step in thin sections." Also; "it is to be regarded as a concretionary formation which has originated in the clay formed by decomposition of rock, and that it is therefore not a simple process but several different processes following each other." He thinks, however, that other kinds of basalt than anamesite can yield bauxite. He also concludes from his microscopic and chemical studies of bauxite that it is the same as hydrargillite. The chemical process and the method of forming the pisolites, he says, is unknown.

Of the theories above mentioned the only one that appears to be applicable to the Arkansas deposits is that of hot waters. This however is not necessarily in conflict with the theory of Liebrich that they are decomposition products, though they are not, in the present case, associated with basalts, and are certainly not formed by the decomposition of any rock *in place*. It is my opinion that before the eruptive syenites had cooled they were sunk beneath the Tertiary sea, and that either by the contact of the sea water or by the issuing of springs whose waters

¹ Memoirs of the Geological Survey of Ireland, Mem. accompanying Sheet 20, p. 12.

had been in contact with the hot syenites the aluminous materials were segregated as pisolite and sank near where they were formed. Thus if the process is one of decomposition it is decomposition in the presence of and due to high temperature.

The irregular forms of the deposits, their variable thicknesses and characters, and, in fact everything known about them, is in keeping with this theory of their origin. Stress has been laid by Meunier upon the fact that so many bauxites rest upon¹ or are associated with limestones; and this fact was used by him to explain the precipitation of the material from chlorides of aluminium in hot sea water. But, as Augé has pointed out, limestones are not always present,² and there are certainly none associated with the Arkansas deposits.

Forms of the deposits.—From what has been said it is evident that the bauxite deposits must be very irregular in form. Although associated with marine sediments of wide and regular distribution, the bauxite deposits are local, irregular and of uncertain extent, for the influences that produced them were local, and the rocks (syenites) with which they are associated are in all probability concealed in many places. The figure given under the head of "origin" on page 275 will give as definite an idea as can be had of the forms of the deposits without prospecting. If, at any time, it should become necessary to prospect for other deposits, the prospecting should be confined to the region in which bauxite is now known and to the soft Tertiary beds. It does not now seem advisable to look for this mineral above an elevation of 350 feet or below 250 feet above mean tide.

Method of mining.—Stripping and quarrying in open cuts is the method to be used in nearly all the deposits known. Of course when the cover becomes too thick it cannot be removed economically, and such deposits will either have to be abandoned or the mining will have to be done by drifts. Persons experienced in the driving of tunnels and mine timbering should

¹ Comptes Rendus, 1883, XCVI, 1737-1739.

² Bull. Soc. Géol. de France, 1888, XVI, 346.

have charge of the work in this stage. The roof is likely to be soft and to require lagging. Furthermore, unless discretion is used in opening quarries and driving tunnels, the operators are likely to have difficulty with the draining of the mines.

THE DISTRIBUTION OF BAUXITE IN ARKANSAS.

In thickness the bauxite beds vary greatly, the greatest found being forty feet, and even in this case the full thickness of the bed is not exhibited. In vertical distribution it has a range of about sixty feet, lying, so far as observed, between 260 and 320 feet above mean tide level. This observation, however, refers only to the Pulaski county deposits, no observations having been made on the vertical range of the Saline county beds, which, however seem to be at, or near, the same elevation. It is not supposed that the exposures now known are the only ones in the state, for it has not been possible to make detailed search throughout the area in which the deposits may reasonably be expected. The number of exposures will probably not only be considerably increased, but it should be added, that inasmuch as sedimentary beds overlie or have overlain some of the known deposits, it is quite possible that there are others yet uncovered by natural processes of erosion.

These bed should be sought only in the areas of soft sands, clays, and gravels and in the neighborhood of the eruptive rocks of Saline and Pulaski counties.

THE USES OF BAUXITE.

Many attempts have been made to use bauxite as an ore of iron, but with poor success or with no success at all. The kaolinic varieties may be found available as kaolins, though I know of no attempts to use them for such purposes. Bauxite has been successfully used for the manufacture of the following materials:

1. Alum.
2. Sulphate of alumina.
3. Aluminum (the metal).

4. Refractory wares, such as furnace linings.

5. It is also available for increasing the refractoriness of fire clays used in the manufacture of fire bricks, furnace linings and the like.

I shall say nothing of the methods employed in the utilization of the raw material. Some of them are described in the works mentioned at the end of this paper, others are guarded as trade secrets, or are covered by patents.

There is one use, however, for which bauxite is available to which I wish to direct especial attention, and that is as a refractory material in the manufacture of iron and steel.

Bauxite as a refractory material.—Bauxite is one of the most refractory materials used in the arts. It is especially valuable for lining blast furnaces where it outlasts the best artificial fire bricks. It is used alone and also as an ingredient for increasing the percentage of alumina in other refractory materials.

In his "Feuerfesten Thone," Bischof speaks as follows of bauxite:¹ "This natural aluminium hydrate which has as yet been found only in a few places, . . . when not impure on account of the admixture of foreign substances, especially of iron, which generally occurs in considerable quantities in compounds of alumina, is extremely refractory. . . . The addition of the varieties free from iron, or the white ones, to other refractory clays offers the only *important means known* of increasing their percentage of alumina, and at the same time their refractoriness. On account of a large percentage of chemically combined water this material shrinks considerably in burning, a fact to be noted in using it." In another place Bischof says:² "Bricks made from calcined bauxite are especially useful in the production of iron and steel in the Siemens revolving furnace."³

Bruno Kerl, an excellent authority on this subject, says:⁴ "Bauxite bricks and crucibles of bauxite, recommended by

¹ Die Feuerfesten Thone, C. Bischof, pp. 193-4,

² Op. cit., p. 277.

³ See also Dinger's Polytechnisches Journal, Vol. CXCVIII., p. 156; ibidem, Vol. CCX., p. 109.

⁴ Thonwaarenindustrie, p. 526.

Gaudin as long ago as 1858, should, when low in iron, withstand heat which would fuse all other refractory materials.

“Bauxite is a compound having a composition intermediate between diasporé and limonite, and consists of hydrate of alumina combined with hydrated oxide of iron.

“On account of the large quantity of water present this mineral shrinks greatly on heating, is usually refractory, and, if it does not contain too much iron, when added to fire clays, increases their refractoriness.

“Siemens used bauxite bricks with 50 per cent. of alumina, 35 of iron oxide and 3 to 5 of silica, which lasts five or six times as long as Stourbridge first-brick. Schwarz recommends for crucibles for manufacture of cast steel a composition of one to two parts Goettweiher clay and two parts of burnt bauxite from Wochein. The bricks of the Compagnie Parisienne at the Vienna Exposition withstood the heat of molten platinum, yet their fracture was like that of stoneware.”

Sir William Siemens tested bauxite as a furnace lining and says¹ of it: “A series of experiments to form solid lumps by using different binding materials have shown that 3 per cent. of argillaceous clay suffice to bind the bauxite previously calcined. To this mixture about 6 per cent. of plumbago powder is added, which renders the mass practically infusible, because it reduces the peroxide of iron contained in the bauxite to the metallic state. Instead of plastic clay as the binding agent, waterglass or silicate of soda may be used, which has the advantage of setting into a hard mass at such a comparatively low temperature as not to consume the plumbago in the act of burning the brick. A bauxite lining of this description resists both heat and fluid cinder in a very remarkable degree, as I have proved by lining a rotative furnace at my sample steel works at Birmingham, partly with bauxite, and partly with carefully selected plumbago bricks. After a fortnight's working the brick lining was reduced from six inches to less than half an inch; whereas the bauxite lining was still five inches thick and perfectly compact. It is

¹ The scientific works of Sir Wm. Siemens, I., London, 1889, 296.

also important to observe that bauxite when exposed to intense heat is converted into a solid mass of emery of such extreme hardness that it can hardly be touched by steel tools, and is capable of resisting mechanical as well as the calorific and chemical actions to which it is exposed.

"The bauxite used in the above mentioned lining was of the following composition :

Al_2O_3	-	-	-	53.62
Fe_2O_3	-	-	-	42.26
SiO_2	-	-	-	4.12 "

Speaking of the value of bauxite as a refractory material Professor Thomas Egleston of the Columbia School of Mines says that it "lasts five or six times as long as the best Stourbridge bricks. Nothing has yet been found which resists the corrosive action of basic slags so well."¹

In a letter to the author regarding bauxite as a refractory material Professor Egleston writes :

"If the material is pure there would be a very large demand for it. With the introduction of basic processes, the demand for basic lining has increased steadily, but on account of the uncertainty of the composition of bauxite, it is being very generally replaced by carbonate of magnesia, which is found in several localities in Europe and is imported both to England and this country."

The results of several analyses of Arkansas bauxites were sent Professor Egleston when he wrote :

"The subject is a very interesting one and may be of great value to the state if it should prove that any of these are aluminates. In some of them I fear there is too much silica, but in any case I think valuable fire bricks could be made of them. I have often tried to interest the fire-brick people in the new processes for the manufacture of these bricks which have been developed within the past ten or fifteen years in Europe, and in the hope of so doing have published several articles on the subject, but the manufacturers have been generally unwilling to

¹ Transactions Am. Inst. M. E., Vol. IV., 261-2.

invest any more capital in their business, which, they say is already very much cut up. If a new industry were started, it could be started on altogether a different basis and I think would easily compete with the old manufactories. This is all the more true since the development of the basic open hearth and Bessemer process in the South calls for a higher grade of fire-brick. I had, while recently in Europe, some important interviews with the proprietors of the magnesite quarries in the west with regard to the introduction of that material into the United States. If your material should prove to be aluminates you could easily compete with them."

Markets.—The processes by which bauxite is manufactured are in some cases patented and the parties owning the patents are alone entitled to use or to dispose of them; in other cases the processes are guarded as trade secrets. Partly for these reasons and partly because the utilization of bauxite is confined to but few companies, the public knows but little of the uses to which the raw materials are put, or of the processes employed in their manufacture.

One thing that has thus far prevented the Arkansas bauxite getting into the market is the fact that the samples sent away have been selected without a knowledge of the composition required or of the material sent. As has been stated, iron, silica, and titanium are the objectionable ingredients, and the percentages of these cannot be determined by simple inspection, though familiarity with analyses of types will enable one to form an opinion of value on this subject.

Another matter of importance is that the freight rates charged by the railways out of Little Rock are so high as to prevent its profitable shipment.

Still another is that extravagant ideas of the value of the ore have induced those who would otherwise have done the mining and shipping to expect very large profits from it. As a matter of fact the value of bauxite at the place of production in the United States during the year 1895 averaged about four dollars¹

¹ Engineering and Mining Journal, Jan. 2, 1897, 3.

a ton. The question for owners and miners is whether the market price will leave them a reasonable margin of profit. The cost of plants for the utilization of bauxite is so great, and the local market for manufactured products so small, that, in my opinion, it is useless to think of factories being established in Arkansas. The factories are all in the north,¹ and the probabilities are that they will remain there for some years at least. In the meantime, if the bauxite beds are to be utilized, the material must be mined and transported cheaply. Labor and teaming are low, but railway freights are high at present. This necessarily prevents Arkansas' competition with the Georgia and Alabama deposits. It is to be hoped that the railways may see their way to offering rates that will allow of bauxite mining in Arkansas.

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¹ The Pennsylvania Salt Company, Natrona, Pa. The Solvay Process Company, Syracuse, N. Y. The Pittsburg Reduction Company, Pittsburg, Pa.

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